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THE DIFFUSION OF ORE-HEARTH SMELTING TECHNIQUES FROM YORKSHIRE TO THE UPPER MISSISSIPPI VALLEY LEAD REGION

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SYNOPSIS

Although the important role of Cornish miners in developing mines around the world has been the subject of books and papers and is well understood, the contribution of other British miners, albeit much smaller, has largely been ignored. Recent studies,[1-3] however, looking at early lead mining in the Upper Mississippi valley region of the United States of America, have shown that many Swaledale families were involved in this area. This paper discusses the impact of these families on lead mining around Dubuque, in Iowa, and in the neighbouring states of Illinois and Wisconsin, and also discusses the interesting period of prolonged stagnation of techniques resulting from the area's frontier conditions. The latter ended with an influx of mainly European miners in the late 1820s.

When the Upper Mississippi Valley Region's Paleozoic rocks were folded, its limestone rocks received a pattern of fractures and joints which allowed hydrothermal emplacement of lead and zinc ores. The ore deposits and their host rocks are, therefore, similar to those in the Pennines. Lead was found as galena and cerussite at three main horizons in the Middle Ordovician Galena Limestone, but it was the upper two which the early miners worked. The ore occurs as rich veins under a cap of clay and shale. Ore was also found in open joints and caves, where it was mixed with the soft, ochreous debris forming the floor. The fissures varied in width from practically nothing to 50 feet. The early miners also worked floated ore, which was found in the soil near outcrops.[4] Zinc occurs as blende (sphalerite), smithsonite and calamine.

Aboriginals produced small amounts of lead for their own use from the Archaic and Early Woodland periods and, in the sixteenth century, passed their knowledge of lead sources to early French voyageurs. Archaeologists found traces of rudimentary smelting hearths at Indian sites but, owing to the lack of detailed evidence from excavation, can only speculate that they were simple log furnaces. At the Little Osage site, in Missouri, for example, clays tone moulds, for small ornaments, and lead musket balls have also been found in Indian contexts.

Forest tribes traded deerskin or fur to get European goods and white fur traders also encouraged the Indians to mine lead ore, which was plentiful and, except in the dead of winter, easily worked. Lead mining

by the Mesquakie, Winnebago, Sauk and, to an unknown degree, by the Illiniwek and Osage, from 1780 to 1840, produced an almost unique situation in eastern North America. What effects this had on settlement patterns, degree of sedentism, economy and social structure is a problem of acculturation which remains to be answered. Nevertheless, in the fur trading period, lead mining became a substantial part of the economic system of the Mesquakie:-[5]

'The ore at these mines is now exclusively dug by the Indian women. Old and superannuated men also partake in the mining labour, but the wariors and men hold themselves above it. In this labour, the persons who engage in it employ the hoe, shovel, pick-axe and crow bar. These implements are supplied by the traders at the island, who are the purchasers of the crude ore. With these implements they dig trenches, till they are arrested by solid rock. There are no shafts, even of the simplest kind, and the windlass and bucket are unknown to them – far more so the use of gunpowder in the mining operations. Their mode of going down into the deepest pits, and coming up from them, is by digging an inclined way, which permits the women to keep a erect position in walking. I descended into one of these inclined excavations, which had probably been carried down forty feet, at the perpendicular angle'.

Burnt limestone bed-rock, found in an opencast and two shallow adits, also suggests that fire-setting was used to break rock.[6]

The region was controlled by Amerindians until the 1820s-1830s, when they were ousted by Euro-Americans, but the French mined and smelted lead in the late seventeenth century, when they also traded in lead from "Indian Mines". French involvement in the lead trade began to decline in 1762, the end of the Seven Years' War, when France ceded the eastern half of the Upper Mississippi valley to the British and secretly turned over the western half to Spain. In 1784, at the end of the America Revolution, the United States acquired the North-West Territory, which included the lead fields east of the Mississippi, from Britain.

Mining continued on a small scale until 1788 when a fur trader, called Julien Dubuque, began trading lead with the Indians. To safeguard his position, in 1796, Dubuque got a grant for his Mines of Spain, which were west of the river, from the Spanish. In 1800, the latter area, as part of Louisiana, was returned to the French, who sold it to the United States in 1803. Dubuque's lead was taken by keel boat to St. Louis where it was sold. When he died, in 1810, he dominated both the production of lead and the fur trade in the region. The Indians continued mining but in 1822 armed miners appropriated their workings and in 1823 the United State's first mineral rush began.

A flood of prospectors and miners came to the lead fields on the east side of the Mississippi and by squatting forced the Indians off their lands. Because the ore was both rich and very shallow, myriad prospecting
pits were sunk as miners ranged the area. After 1828, the number of mining grants made on the east bank increased rapidly. The miners also made illegal attempts to cross to the west bank but, until the area was opened for mining in 1833, they were turned back by the army. Nevertheless, the Indians were angered by the repeated incursions and rumour of an impending attack spread panic amongst the miners, who returned to the settlement of Galena. The Indians did not attack, however, and miners went back to their diggings.

Squatters even took over a Sauk village, which was the ancient tribal seat, at the mouth of Rock River, Illinois, where they enclosed the corn fields and dug up Indian graves. Black Hawk, the elderly chief, was forced to move his people to Missouri territory where they faced starvation and hostile Sioux. In an attempt to find new lands, Black Hawk and 1000 of his tribe, including women and children, crossed the Mississippi but were intercepted by the Illinois Militia. The latter, including Abraham Lincoln as a Company commander, misinterpreted the situation and shots were fired. The Sauk continued northwards, into what became Wisconsin, followed by several hundred regular troops and 2000 militia. An armed steamboat, the *Warrior,* supported by foot soldiers, intercepted the tribe at the confluence of the Bad Axe and Mississippi Rivers but Black Hawk's attempts to surrender were ignored and all but 40 of the 1000 were slaughtered. This massacre and the treaty of September 1832 ended all significant Indian involvement in the region's mines.

In the 1820s, the miners of the Fever (Galena) River district paid a duty of one-tenth, in smelted lead, to the federal government. This was difficult to enforce, however, and in 1825, the system was rationalised to make collecting dues easier and to stimulate deeper, more intensive, mining. Three types of mining permit were introduced. The first, for a smelter's licence, allowed the holder to buy and smelt ore got in the public lands. The smelter paid a bond of $10,000 and then ten per cent (reduced to six in 1830) of the metal produced. For the second, a five year mining lease, on 320 acres, the taker paid a bond of $5000 and undertook to employ 20 men at all times. The majority of miners, however, worked under the third option, a digger's permit, which had a short life and restricted mining to a specific tract of ground, 200 yards square. The miners were compelled to sell their ore to a licenced smelter.

At first, ore was so plentiful and free from gangue that dressing it needed little sophistication, being confined to washing and hotching. Later, however, as mines went deeper, increasing contamination by zinc ores made it harder to separate the galena. Most of the lead was smelted locally, using the area's timber, but in the last quarter of the nineteenth century, when production was mainly zinc blende, ore was shipped to smelting works on the coalfields.

The crude smelting techniques used by the aborigines, French and early Americans, from the seventeenth to the early nineteenth centuries, were similar to boles, which English smelters abandoned before 1600. There were two types of wind blown furnace, the log hearth and the trench hearth:-[7]

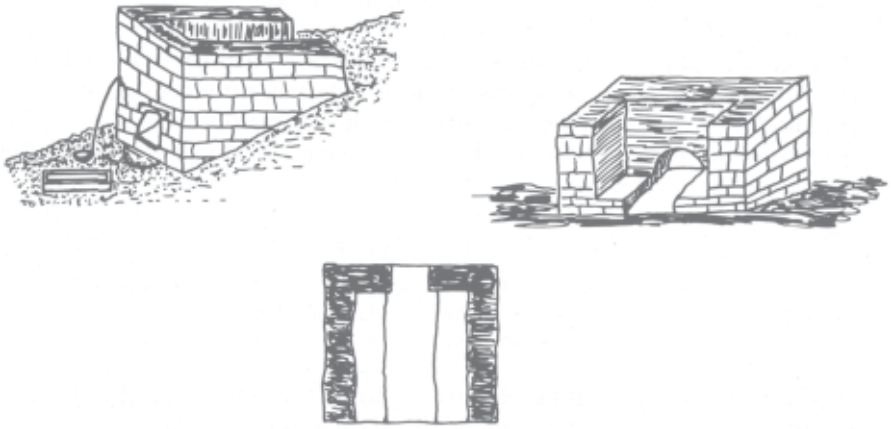
'The log hearth was simply a trench dug into a hillside that was filled with logs on which the ore was thrown. The fire would be started in the evening, and in the morning the lead would be found at the bottom of the trench, where it had consolidated into shapeless lumps or had trickled into small holes that had been scratched in the earth under the logs'.

It is not known what type of furnace Julien Dubuque used but it may have been an improved version of the trench type, like those used by the Mesquakie at Dubuque's mines in the early nineteenth century:-[8]

'A hole, two feet deep, and as wide at the top, was dug in the face of a hill slope, this hole tapered like a mill-hopper and was lined with flat stones. Across the lower end, which was about eight inches square, narrow stones were placed gratewise. A channel was filled with dry wood and brush, which, when ignited by the molten lead, served to maintain its liquidity. The flat ingots, called plats (or plates), by the French, weighed about 70 pounds apiece, or about the same as the pigs of later days'.

By the 1820s, an improved type of log furnace was in use. It would, nevertheless, have been familiar to Agricola:-[9]

'The log furnace was built upon a bank or hillside so as to have a descent of forty-five degrees. They were built on two or four eyes. In the first place there was a strong wall built parallel with the bank, connected with walls at right angles, four feet apart. After the walls were up, there was a hearth laid, made of one flag-stone having the proper inclination so that the lead would flow down into the basin in front of the furnace. The hearth being made, there were side walls placed upon the hearth, nine inches high, and from nine to twelve inches wide. As burners for the logs, stoke holes were left in the front wall, ten inches wide by twenty inches high. Logs were cut of a proper length, say three feet ten inches long, and from fourteen inches to two feet in diameter. The large logs were first rolled in upon the side walls, which raised them from the hearth to leave room for air and wood. After the logs were properly placed, the barking was set, that is, wood set upon the end around against the walls. That being set, it was ready for the mineral. Each eye would receive from three to four thousand pounds. The furnace being charged, a slow fire was kindled under the logs, and continued to burn until it arrived at a dull red heat. The fire was then drawn from below to give time for the sulphur to pass off. The sulphur, logs and barking would keep up a moderate combustion, which was left about six hours. It was then ready to have a fire kindled again in the eye under the logs. A brisk fire being kept up, the lead would flow down into the basin, which was kept hot by a fire upon it until the lead was cast into pigs'.



The entire operation of charging the log furnace with wood and ore, and of smelting and casting the lead into pigs took about 24 hours.

Smelting in the bole-type hearths used by the Indians was inefficient and caused great losses of lead, and the traders bought their lead-rich slags for res melting in an ash, or slag furnace. In the early nineteenth century members of the Mesquakie, Sauk, Winnebago and Iowa Indians were mining for galena, collecting lead slags, smelting galena, and trading ore, slags and pig lead to white traders. Dr Moses Meeker, who mined near Hazel Green, gave the following description of the slag smelting furnace:-[10]

'The next process, when there was a sufficient quantity of ashes accumulated, was to wash them clean from extraneous matter, that they could be fused by a higher degree of heat in a furnace called an ash furnace. The ashes when clean were composed of small pieces of mineral, and the grey oxide of lead. The ash furnace was likewise built upon the side of a hill, but entirely different in construction from the log furnace. There were walls raised about three feet high, and eighteen inches apart, and five feet long for the ash pit. The original mode of making the grate was by laying rocks transversely. The fire-place was constructed so that the blaze was thrown upon the basin. The basin was constructed in an oval shape, and so that it could be tapped on both sides of it, one side for the slag and the other for the lead and zane. Zane was a term made use of to designate lead that was not deprived of its mineralised sulphur, which had to be passed again through the log furnace; it was then a fine lead. From the basin there was a flue, somewhat funnel shaped, at an inclination of forty-five degrees, with a flat hearth, and at the top was a place to put the ashes upon to be smelted, which was pushed into the flue as it melted off the bottom and ran down into the basin. The ash furnace was kept going day and night until the bottoms of the flue and basin were cut down by the action of the sulphurate of lead combined with heat. When I came to the mines it was considered a good ash furnace that would run fifty thousand pounds of lead, but they were subsequently much improved, that a hundred and sixty thousand pounds were made by one furnace before it went into disuse'.

Reverberatory furnaces, like the one above described by Meeker, were used in Britain from the late seventeenth century. The body of the furnace and all parts of the advanced log furnace were first built of limestone rubble or solid masonry. The former, in particular, was lined with limestone slabs in a clay mortar. The structures had short working lives, however, because the heat and gases from smelting reacted quickly with limestone and converted it to quicklime. Later furnaces, with refractory brick linings, lasted much longer. Schoolcraft's claim that a silica-based flux was added during smelting to give a black, glassy slag is unlikely.[11]

From the foregoing, it is clear that there was a long period when, by comparison to European experience, smelting techniques stagnated. The reverberatory slag furnace was the only real innovation in over two centuries before the influx of European miners in the late 1820s. Even by 1830, except for the treatment of slags, the smelting process was mediaeval by comparison to European standards. This was a result of the frontier's lack of infrastructure, mill-wrights etc., which were necessary to build even a small water-powered smelting mill.

Nevertheless, the conditions imposed, in 1825, by the federal government's revised mineral leasing system encouraged both greater output of ore and the centralisation of smelting. To satisfy both conditions demanded the adoption of more efficient furnaces, many of which seem to have been introduced by Yorkshiremen.

The Yorkshire Connection

Lead mining let the populations of many mid and north Pennine dales exceed what their agriculture could support in the eighteenth and nineteenth centuries. Nevertheless, a constant outward migration kept these communities a fairly constant size, varying only with the fortunes of the lead industry. For example, the population of Swaledale and Arkengarthdale, in Yorkshire, peaked at 8,279 in 1821 and has declined ever since.[12,13]. Families from Swaledale went to the Burnley area, in Lancashire, where the men worked in collieries, and the textile industry provided work for their wives and daughters. In the late 1820s and early 30s, when low lead prices caused prolonged unemployment, some lead miners went to America, where mines were opening. The number who chose to emigrate was, however, only a small percentage of those leaving the dale. In spite of this, between 1825 and 1850 around 250 men, women and children left the Yorkshire Dales, especially Swaledale and Arkengarthdale, for the Upper Mississippi valley region.[14] Others went from the northern Pennine orefield.

Most of the men were lead miners and smelters who also had a long tradition of involvement in farming, which made them ideal for exploiting the Dubuque area.[15] Moreover, unlike those from Derbyshire, Cornwall and most of Wales, Pennine smelters were familiar with ore-hearths, which were ideal for frontier conditions, being fairly unsophisticated and able to burn Wood.[16,17] They could also smelt larger quantities of ore more efficiently than existing American furnaces, giving a product of around 70-75 per cent.

The precise nature and timing of this change remains to be confirmed, however, because various authors have either confused furnace types or disagree about names and dates. For example, Abbott[18] claimed that '(In) 1834 Peter Lorimier erected a Scottish hearth on Catfish Creek. This hearth was apparently still in operation in 1897'. According to the authors of a detailed archaeological report[19] on the mines, however, 'In 1834, French Canadian Robert Lorimier built a cupola furnace at the mouth of Catfish Creek'.

There is a similar contradiction in Abbott's note[20] that in '1836 the Drummond blast-furnace was introduced into the Galena area' and David Morris's claim[21] that Robert Drummond used a reverberatory furnace. It is likely that the term blast-furnace was used to describe an ore-hearth. A cupola was a reverberatory furnace.

Irrespective of which type of furnace Lorimier and Drummond used, neither of them made a significant impact and it was dalesmen who built and ran the first true smelt mills. The following examples of smelt mill owners, who originated in Swaledale, is arranged chronologically and draws heavily on the work of David Morris.

Robert Bonson left Swaledale in 1834 and, with Robert Waller, a smelter from Whitaside, and others, built a smelt mill at Platteville, Wisconsin. This is claimed as the first blast furnace (ore-hearth) for smelting lead in America. In the same year, Benson and partners built another two furnaces, one of which was at Big Patch, south-west of Platteville.

Martin Spensley, from Swaledale, was living in Galena by 1830. He combined with John Spensley and James Calvert to form Spensley & Company, a smelting concern at Mineral Point. Mason and Ralph Spensley became partners in a smelt mill near Dubuque in 1850. Later, there was also a firm of Dubuque lawyers called Spensley and Spensley.

In 1836, Major Manning built an ore-hearth, to specifications provided by John Spensley of Dubuque, in Missouri's Washington County. Another settler, George Cresswell (b.1796), from Derbyshire, also went to Washington County in 1821 and founded an agricultural plantation and lead business in the 1830s. Spensley corresponded with Cresswell in 1837 and informed him that the cast iron components of a hearth were ready. The first recorded production from the latter was in 1841.[22]

Joseph Brunskill emigrated to Akron, Ohio, where he worked as a wood chopper and labourer for three years before moving to Dubuque to become a miner. In 1845, however, he built a smelt mill in the Rockdale valley.

John Watters, a lead smelter who left Gunnerside in 1845, built a smelter north-west of Rockdale. This mill, still working in 1912, was worked by three generations of his family and was the last in the Dubuque area.

George Reynoldson left Swaledale in 1845 and ran a smelt mill at Center Grove. He also had a tanning yard and, later, a leather business in Dubuque.

The precise location of the above smelt mills is unknown and more archaeological fieldwork is, therefore, needed before the spatial relationship of the region's mills can be defined. Nevertheless, archaeological field surveys have found the sites of two near the mouth of Cat Fish Creek. One is associated with cultural material which suggests that it is the ore-hearth mill, which worked from the 1830s. The other, which is stratigraphically lower and may have been run by Julien Dubuque or his successors between 1810-1834, was either an improved trench furnace or an advanced log furnace.

The region's output peaked in 1847, when about 22,300 tons were produced. By this time, however, the shallowest workings were exhausted and shafts, which were sunk to between 50 and 150 feet deep, were being abandoned on meeting the water table. Many miners, tempted by the lure of gold, left for California in 1849. They had the

advantage of skills and familiarity with American mining law, which served them well in the gold diggings. Nevertheless, some Dalesmen still went to the Upper Mississippi area and, in 1889, one John Frankland died in his 80th year. He had gone to Wisconsin around 1867 to work in the mines.[23]

As the region's mines declined, it became settled and its economy more varied, with farming, flour milling and the timber industry growing in importance.

Its river trade with the south became less important when, in 1855, Dubuque was linked to Milwaukee and Chicago by railway. By the 1860s, farming surpassed mining as the region's most important industry. Also, the majority of Dubuque's population came from other countries, mostly Ireland and Germany, whilst the Yorkshire immigrants had settled along the Fever River. Unlike their Cornish counterparts, however, who remained a distinct ethnic group and tended to move on quickly, the Dalesmen integrated with American culture and settled the land.

Many historical studies of European mining, especially those concerned with the evolution and spread of new machinery and ideas, claim that diffusion was the mechanism in play. Recent work[24,25] has, however, questioned this, but the foregoing is a clear example of technological transfer.

Miners from the Pennine dales, especially Swaledale and Arkengarthdale, were in the forefront of what was the United States' first major mining rush. They introduced smelting techniques which made possible the surge in output and put America on the road to dominating World production of many metal ores. The mining law developed in the region was also used on the Far Western mining frontier, of which it was the precursor.

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